

Validating a Response to Intervention Multitiered Model for Primary Grade Students With Mathematics Difficulties

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Purpose of the 4-Year Project

Develop and validate mathematics interventions by comparing the outcomes over time of students in first and second grades who were identified as being at risk for mathematics difficulties and received:

- “standard practice” mathematics instruction delivered by a general education teacher or
- a replacement intervention delivered by trained tutors.

Background: Rationale

- Approximately 5% to 8% of school-age children exhibit some form of mathematics disability (Gross-Tsur, Manor, & Shalev, 1996; Ostad, 1998) that may go undetected until students attempt more advanced mathematics instruction, such as in fractions and algebra.
- There is an increasing focus in current research on identifying students in the primary grades who are at risk for mathematics difficulties and on validating multitiered interventions aimed at prevention and remediation (Bryant et al., 2008; Chard et al., 2008; Fuchs, Fuchs, & Hollenbeck, 2007; Gersten, Jordan, & Flojo, 2005).
- Provisions in the Individuals with Disabilities Education Improvement Act (2004) emphasize prevention and intervention as part of the process to determine whether students have learning disabilities.

Background: Early Numeracy & Number Sense

- The ability to understand number, operation, and quantitative reasoning concepts and skills is one of the most important areas of early numeracy instruction (Clements & Sarama, 2004).
- Core number sense or number competencies (e.g., numerical values of small quantities, basic counting skills, numeral recognition) develop informally prior to starting school (National Mathematics Advisory Panel [NMAP], 2008; National Research Council [NRC], 2001, 2009).
- Advanced number sense or number competencies (e.g., understanding place value concepts, ordering and comparing numbers and quantity, developing counting strategies) develop through more formal instruction (NMAP, 2008; NRC, 2001, 2009).

Purpose

- Preventing learning problems at an early age is important for mathematics performance. There is a need for developing and validating interventions that promote conceptual understanding of foundation skills and that include the critical features of instruction for struggling students (NMAP, 2008).
- The purpose of this presentation is to present the findings, from Years 1 (first grade) and 2 (second grade) for Cohort 1, on the effectiveness of a Tier II preventative intervention to improve the mathematics performance of students identified as having mathematics difficulties.

Research Question

What are the effects of the Tier II Early Numeracy Booster (EMB) lessons on the mathematics performance across time of at-risk students when compared to at-risk students receiving “standard practice” mathematics instruction in general education classrooms?

Sample: Year 1

- 777 first-graders from 10 elementary schools (central Texas) participated.
- Initial assessment (September): 269 students scored below the cut score (below the 35th percentile) on the mathematics screening measure (local norms).
- 31 students were omitted because of disabilities or English language learner (ELL) status.
- Additional assessments (October): The remaining 238 students were tested four times, using alternate forms of the test.
- Application of the “best fit” cut score identified 224 (94%) students as being at risk for mathematics difficulties, of which two-thirds ($n = 150$) were assigned to the treatment group and one-third ($n = 74$) to the comparison group. The remainder were assigned to the Tier I group.
- Year 1, first grade, end of year: $E = 139$, $C = 64$.

Sample: Year 2

- 692 second-graders from eight elementary schools participated.
- We continued to work with the same group of eligible students (no new students were added to Cohort 1 in second grade).
- At the beginning of the year, we retested the “still enrolled” 101 intervention and 59 comparison students to confirm (a) exit from intervention, (b) still Tier II, & (qualify for Tier III status-<10th%ile):
 - Students who scored at or above the 35th percentile were exited from the intervention ($n = 34$) and comparison ($n = 13$) groups.
 - 4 intervention students and 2 comparison students were exited to SED (1 comparison student was withdrawn from the study).
 - Students who scored between the 10th and 34th percentiles remained in Tier II intervention ($n = 50$) or comparison ($n = 28$).
 - Students who scored below the 10th percentile became Tier III intervention ($n = 13$) or comparison ($n = 15$) students.

Participant Demographics

Free and reduced lunch	(School district)		39%
Ethnicity		E	C
	AA	8.1%	12.8%
	H	27.0%	29.9%
	W	51.4%	35.9%
	A/PI	13.5%	21.4%
Gender	Male	45.9%	45.3%
	Female	54.1%	54.7%

Design

Multigroup growth modeling with random assignment to intervention condition


Measures

- ***Texas Early Mathematics Inventories - Progress Monitoring (TEMI-PM):***
 - Developed and validated 2004-2007
 - Three forms (A, B, C)
 - Four subtests: Magnitude Comparisons, Number Sequences, Place Value, and Addition/Subtraction Combinations (group administered, 2 minutes each)
 - Aggregate Total Score (TS) of the four subtests used to measure fall, winter, and spring student performance—most robust indicator of performance of the four constructs
 - Alternate forms reliability - immediate test/retest:
1st grade coefficients ranged from .76 to .81, TS median = .89;
2nd grade coefficients ranged from .83 to .87, TS median = .93

Measures (cont.)

- **SAT-10:**
 - Primary I (Mathematics Procedures [MP] and Mathematics Problem Solving [MPS]), Total Mathematics Score (TMS)
 - Concurrent validity of spring Form A TEMI-PM TS with the Total Mathematics score of the SAT-10 = .72

Using Grade 1 Number Sequences as an Example...



Number Sequences


Page markers

Demonstrations

2	3	__
1	3	
5	4	


19	__	21
20	19	
17	11	

__	54	55
53	52	
55	63	



1

Practice



1	2	__
1	3	
5	13	

16	__	18
5	19	
17	21	

__	81	82
19	79	
83	80	

6	__	8
7	5	
3	10	


__	1	2
3	4	
0	11	

3	4	__
11	2	
5	6	

__	8	9
1	4	
7	0	

1	2	__
5	0	
3	13	

13	14	__
14	15	
2	1	



STOP signs

2

Intervention: Conceptual Framework

- Goal: Mathematical understanding: Development of conceptual, strategic, and procedural knowledge & understanding
 - Mathematical models: Representations to develop and build understanding (concepts, operations, relations, properties; NRC, 2001) and vocabulary
 - Instructional design features: Sequence of skills and concepts, systematic instructional routine, student engagement - verbal (“Why . . .”) and visual explanations (“Show me . . .”)
 - Procedural fluency & automaticity: Review and practice

Domain: Number, operation, & quantitative reasoning (embedded problem solving, algebraic concepts) (Examples)

- **Number knowledge and relationships:**
 - Count in units and multiples of hundreds, tens, and ones.
 - Read and write numbers (0-99, 0-999).
 - Compare (quantity discriminations) and order numbers.
- **Groups of tens and ones and place value concepts:**
 - Develop understanding of base-ten numeration.
 - Use models to represent groups.
 - Create equivalent representations of quantity.
 - Compose and decompose numbers.
 - Add and subtract multi-digit whole numbers.
- **Addition and subtraction combinations:**
 - Solve problems using properties of addition (algebraic readiness: commutativity, associativity) and inverse relationship of subtraction.
 - Develop and apply cognitive strategies to solve facts with fluency.

Intervention: Components (cont.)

- **Mathematical Models/Representations (Concrete-semi-concrete-abstract sequence):**
 - Concrete: 3-dimensional manipulatives (e.g., connecting cubes, base-ten materials)
 - Visual/pictorial: 2-dimensional (e.g., 100s charts, ten frames, dot patterns for facts, number lines)
 - Abstract/symbolic (numbers and mathematical symbols) (e.g., fact cards)
- **On Going Progress Monitoring (response to intervention):**
 - Daily checks (lessons for the day)
 - Unit checks (multiple skills from the unit)
 - Aim checks (fluency)
 - Fall-Winter-Spring

Intervention: Example

Strategy Time

Objective: The student will be able to use the Make 10 + More strategy to solve addition facts.

Vocabulary: Add, equals, plus, strategy, turnaround fact

Instructional Content: Addition facts to 17 (Make 10 + More)

Materials: • Teacher Master pp. 4–7 • Ten frames and chips (T&S)

Warm-Up: Facts

Look and Say: Hold up fact cards. Students quickly say the answer. Put missed facts in a pile. Use error-correction procedures.

Review

Today we will learn a strategy to add numbers up to 17. It is the Make 10 + More strategy.

Review: $7 + _ = 10$, $8 + _ = 10$, $9 + _ = 10$.

Review: $10 + 1 \text{ more} = _$, $10 + 3 \text{ more} = _$, $10 + 2 \text{ more} = _$,
 $10 + 9 \text{ more} = _$, $10 + 7 \text{ more} = _$, $10 + 6 \text{ more} = _$, $10 + 5$
 $\text{more} = _$, $10 + 4 \text{ more} = _$, $10 + 8 \text{ more} = _$.

Intervention: Example (cont.)

Modeled Practice (My Turn, Your Turn)

1. Place the Modeled Practice sheet on the table. Have students look at their Modeled Practice sheets. Introduce the Make 10 + More strategy, using the fact $9 + 4$.

There are 3 steps to remember.

Step 1: Check the fact; is there a 7, 8, or 9 in it? (yes)

There is a 9 in this fact.

Step 2: Make 10.

9 plus what equals 10? (1)

My Turn: I take 1 chip from the group of 4 to put with the group of 9. (Move the counter from the dotted circle along the dotted arrow to the empty box in the top ten frame.)

I know that $9 + 1 = 10$. I made 10!

Your Turn: Make 10.

Step 3: 10 + More.

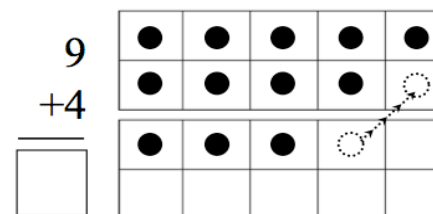
I have 10 in 1 frame, plus 3 remaining chips.

What is $10 + 3$? (13)

So $9 + 4 = 13$.

What is the turnaround fact? ($4 + 9 = 13$)

Unit 9
Booster Lesson 1
ASC Day 1
Modeled Practice
Strategy Time



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Procedure

- **Units and lessons:**
 - 10 units, eight lessons per unit
 - Sequenced skills and concepts within and across units
 - Daily components: A warm-up (3 minutes, review facts, write numbers) and two lessons
 - Explicit cognitive strategies and timed practice (procedural fluency building)
- **Critical features of instruction:**
 - Student engagement and responding
 - Instructional routine: Review (pre-skills), Modeled practice (e.g., worked examples), guided practice, independent practice
 - Multiple opportunities to practice and review
 - Examples (for the new lesson; from previous lessons [discrimination])
 - Checking for understanding
 - Error correction
 - Pacing
- **Grouping:** Small groups of 4 - 5 students
- **Duration:** 19 weeks 4 days per week 25 to 30 minutes each

Procedure: Training (cont.)

- **Tutors:**
 - Five to seven tutors with degrees in education (general education and/or special education certification) and teaching experience $M = 3.4$ years (range = 0-7 years [0 = student teaching])
- **Initial training:**
 - Half-day
 - Instruction on intervention lessons
 - Review of explicit, systematic instruction
 - Review of “Math Ready” behavior management techniques
 - Peer practice
- **Monthly training:**
 - Instruction on new units

Procedure: Fidelity of Implementation

- Degree to which tutors:
 - Followed the scripted lessons for the content (e.g., modeling, guided practice, independent practice)
 - Implemented the features of systematic instruction (e.g., pacing, error correction, minimal “teacher talk,” engagement)
 - Managed student behavior (e.g., use of reinforcers and redirection)
 - Managed the lesson (e.g., use of timer, smooth transitions between booster lessons)
- 0-3-point scale:
 - 0 = Not at all
 - 1 = Rarely
 - 2 = Some of the time
 - 3 = Most of the time
- 14 observations across two observers:
 - Average ratings exceeded 2.5 in all areas
 - No single rating < 2.0
 - Majority of ratings 3.0

Method & Analyses

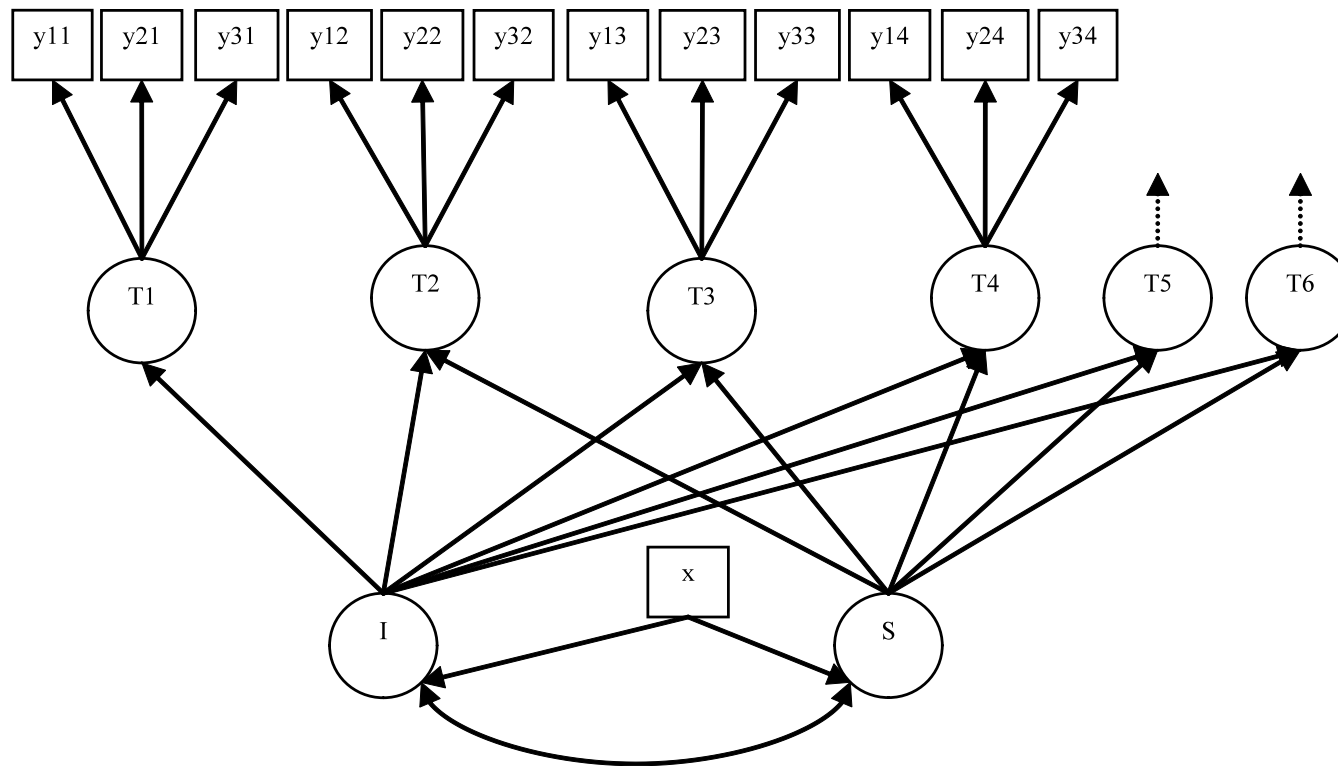
- Year 1: Comparison of marginal means (no significant school-level or class-level clustering)
- Years 1 and 2: Multiple indicator, multilevel growth model (Wu, Liu, Gadermann, & Zumbo, 2009)
 - TEMI administration modified between Year 1 and Year 2
 - Assumes measurement invariance across time
- Measurement model estimates relationships between observed variables and latent factors at points in time
- Structural component represents change in the latent factors across time in terms of growth parameters, including intercept and slope
- Dummy-coded covariates used to evaluate group differences

Results: Year 1

Results: Yr 1: Posttest Results by Outcome Measure - Adjusted Posttest Means

	Comparison (n = 64)	Treatment (n = 139)	F	Sig.	Partial eta ² (η^2)
SAT-10 Math Proc	92.19	95.87	3.65	.05	.02
SAT-10 Math PS	88.27	89.83	1.01	.32	.00
SAT-10 Total Score	89.39	91.82	2.19	.14	.01
TEMI-PM Mag Comp	32.99	34.62	2.02	.16	.01
TEMI-PM Numb Seq	15.70	18.98	13.78	<.01	.06
TEMI-PM Place Value	15.62	17.88	9.72	<.01	.04
TEMI-PM +/- Combo	13.68	17.58	16.34	<.01	.07
TEMI-PM Total Score	78.00	89.1	14.94	<.01	.06

Structural Model



Results: Years 1 and 2

- There were no differences in the unconditional linear and unconditional piecewise models.
- The linear model fit was adequate ($\chi^2 = 201.6$, $df = 154$; CFI = .89, TLI = .88; RMSEA .90 CI = .039-.096).
- The treatment and comparison groups differed significantly on slope ($p < .01$).
- Treated participants outperformed the nontreated group by about .42 of a standard deviation on the spring of second grade latent factor.
- Treatment group outperformed comparison on the Math Procedures [calculation] SAT-10 (standard scores = 92.58 v. 87.78 $p=.025$)

Discussion

- **Overall findings:**
 - Students who participated in the intervention performed statistically significantly better on measures of early mathematics numeracy skills and concepts than students in the comparison group from the same classes and schools.
- **Exit status:**
 - End of first grade: 46% of treatment students and 22% of comparison students were eligible to exit Tier II (scored at or above 35th%ile).
 - End of second grade: 58% of treatment students and 33% of comparison students were eligible to exit Tier II (scored at or above 35th%ile).

Discussion

- **Future research possibilities: Investigation of**
 - Core/Tier I instruction
 - Tier III intervention
 - Classroom teachers delivering Tier II intervention
 - The magnitude comparisons construct; examination of errors to determine possible patterns
- **Implications:**
 - At-risk students can benefit from supplemental intervention.
 - Students benefit from a focus on important foundational concepts and skills (National Council of Teachers of Mathematics, 2006; NMAP, 2008).
 - Principles of effective instructional design that include practices to develop and enhance procedural knowledge as well as conceptual understanding are critical to improving mathematics performance.